3/17/63

[redacted]

7 June 1963
HAN:pa:204

[redacted]
P. O. Box 2143
Main Post Office
Washington, D. C.

STATINTL

Attention: [redacted]

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[redacted]

As a result of discussions between you and members of our technical staff, we are pleased to submit this suggested program for a Microdensitometer Capability and Interpretation Study. The results of the study would be presented in the form of a handbook suitable for indoctrination of individuals into the art of microdensitometry.

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To meet the study requirements listed in Appendix A, a four-task program is suggested with effort being concurrent on all tasks. For budgetary purposes, we estimate the cost of this program to be in the order of [redacted] A final report would be submitted ten months after contract go-ahead.

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If a more limited program is desired, several study and experimental subtasks could be deleted at the expense of generality of the results. These subtasks are identified in the enclosed Work Statement. We estimate that the minimum program would cost approximately [redacted] and the results would be reported seven months after contract start date.

We are very interested in conducting this study and feel that our extensive background in all aspects of microdensitometry uniquely qualifies us to perform this work. As a not-for-profit, nonmanufacturing institution, we are in an excellent position to conduct surveys in the state-of-the-art and evaluate the results in a detached and objective manner.

The enclosure presents a suggested Work Statement, technical discussion, personnel biographies, related project descriptions, and a description of experimental equipment and facilities.

In the event you are interested in our suggested program, we will request our Contracts Department to enter into formal negotiations.

This Laboratory possesses a Top Secret facility clearance.

If you desire additional information, please contact me.

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Yours truly,

[redacted]
Systems Research Department

Enc.

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[redacted]

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MICRODENSITOMETER CAPABILITY AND INTERPRETATION STUDY

10 June 1963

CONTENTS

I. INTRODUCTION AND SUMMARY

A suggested Microdensitometer Capability and Interpretation Study is outlined and discussed. The results of the study would be presented in the form of a handbook suitable for indoctrination of individuals into the art of microdensitometry.

To meet the study requirements listed in Appendix A, a four task program is proposed, with effort being concurrent on all tasks. The first task relates to microdensitometer applications and techniques for data collection and interpretation. The second task is a review of the state-of-the-art of microdensitometry and a survey of available equipment, while the third task consists of studies of the feasibility of several concepts which can potentially advance the state-of-the-art. The fourth task is the preparation of the study report in the form of a handbook.

The program proposed meets the requirements of Appendix A. If a minimum program is desired, several study and experimental sub-tasks could be deleted, at the expense of generality of the results of the project. These sub-tasks are identified in the Work Statement.

The Laboratory has for several years been actively engaged in all of the aspects of microdensitometry. During project PHOTOREK,* a study of atmospheric contrast reduction, an extensive data analysis program was conducted involving photographic photometry. Early in this project, a survey of microdensitometers available at that time was conducted and led to the recommendation of a modified version of an [redacted] Model 4 micro- STATINTL densitometer which was subsequently purchased by the Air Force. This Laboratory is in a unique position to conduct this and similar surveys because of its not-for-profit, non-manufacturing status. On another project

* This and following projects are described in the related projects section of this proposal.

(Q-CAR), investigations of the extraction of image quality (grain, contrast, transfer function) and system performance by microdensitometry have been conducted. Internal research projects are also in progress studying the effects of film granularity and the improvement of data analysis techniques for quality measurement. Under project GRAFORM, the problems of microphotography and enlargement of microphotographic detail have been studied. The potential of lasers as light sources are also under investigation for related problems where high intensity coherent sources are needed.

The following sections are a suggested statement of work, a discussion of technical problems and approach to solutions, biographies of personnel, descriptions of related projects, and description of experimental facilities and equipment.

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II. SUGGESTED WORK STATEMENT

The tasks outlined below are necessary to meet the requirements listed in Appendix A. A more limited program, providing less generality, could be conducted by deleting the tasks marked by an asterisk. A manpower breakdown of the tasks is presented in the proposed schedule which follows the statement of work.

TASK I Mensuration Procedures and Data Interpretation Study

A. Mensuration Procedures

1. Specific applications of microdensitometry such as photographic photometry and photographic system performance analysis will be studied.

2.* Error limits for possible mensuration techniques will be experimentally determined.

B. Data Interpretation Considerations

1. Resolution and light source coherence effects on density determination reliability will be investigated.

2. Grain scattering effects on specular and diffuse density determination will be studied.

3. Aperture and magnification selection, with respect to noise removal and nonlinear density integration, studies will be performed.

TASK II Equipment Capability Study

A. Existing Instruments Survey

Manufacturers of microdensitometers will be surveyed and instrument features correlated.

B. Classification of Microdensitometers

C. Microdensitometer Sensitivity

Noise sources and response times will be considered in determining instrument sensitivity.

TASK III Feasibility Studies

A. Visual Display

1. Visual display techniques, both optical and cathode ray oscilloscopes, will be studied.

2.* The effectiveness of incorporating a visual display into a microdensitometer will be experimentally evaluated.

B. Photo Micrograph

1. The feasibility of recording scanning images by means of microphotography will be studied.

2.* The effectiveness of recording scanned images will be determined by experiment.

C. Laser Light Source

1. Laser intensities in various operating configurations will be studied.

2. A study of the degree of coherence of lasers will be conducted.

3.* The feasibility of phase aperture shaping will be investigated.

4. The maintainability, lifetime, and auxiliary equipment requirements of lasers will be studied.

5.* Experiments related to coherence and phase aperture shaping will be conducted.

D. Standard Density Wedges

1. Available density standards will be surveyed.

2. Various media will be tested to determine their suitability for use in a general density wedge standard.

E.* Color Densitometry

1. The design of a color microdensitometer will be considered.

2. Tests of color densitometry effectiveness will be performed.

TASK IV Documentation

A. Monthly Progress Reports

B. Final Reports

1. The results of Task I will be reported in the form of a microdensitometry handbook.

2. The results of Tasks II and III will be reported.

The following chart is a schedule of tasks. The subtasks which would be deleted in a minimum program are indicated by shading. It is estimated that our suggested program will require 40 man months while a minimum program which is less general will require 26 man months.

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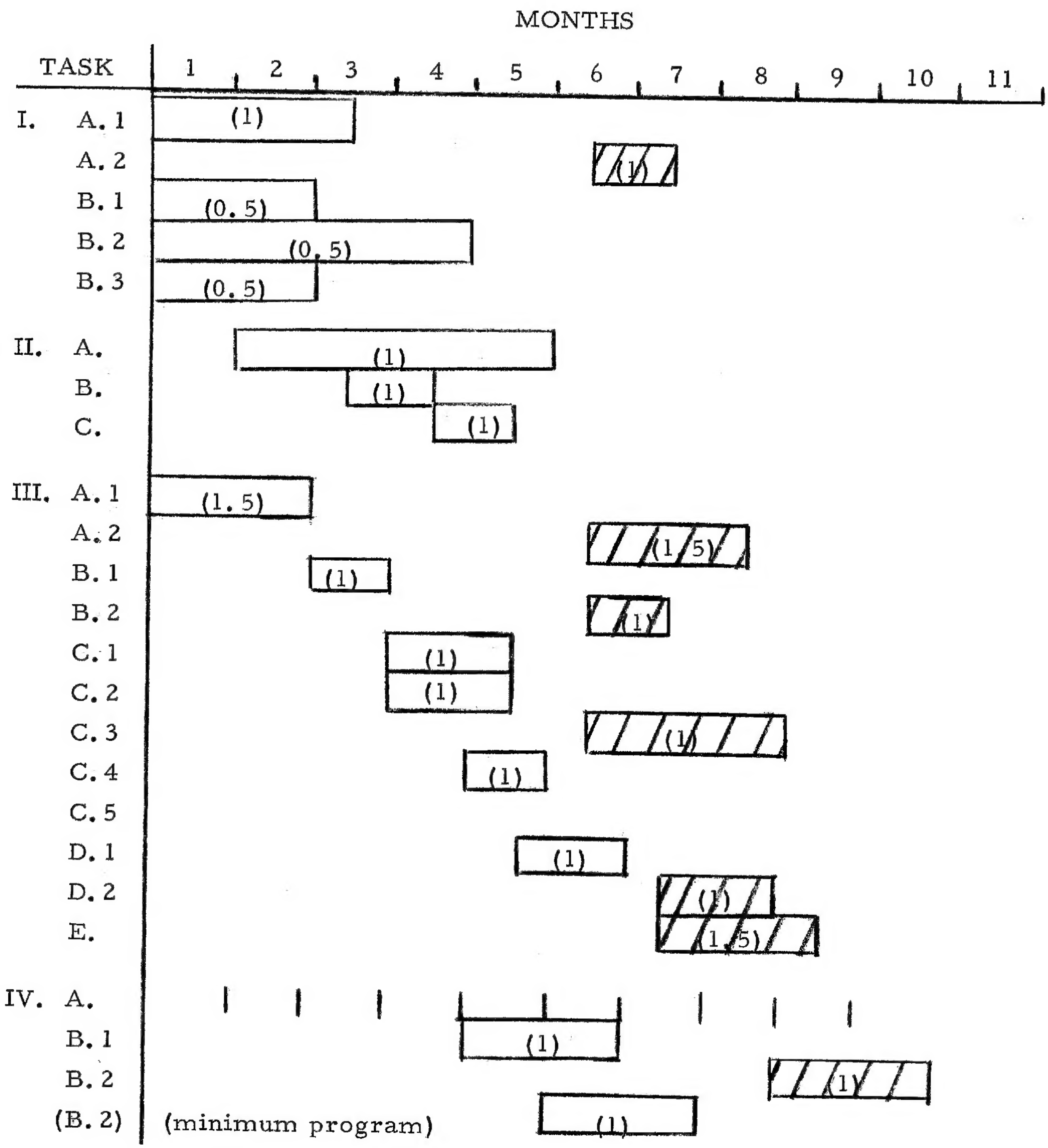
SCHEDULE AND MANPOWER ESTIMATES*



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* Numbers in parentheses indicate manpower level.

III. TECHNICAL DISCUSSION

The following discussions are divided according to four tasks; mensuration procedures and data interpretation, equipment capability, feasibility studies, and report preparation.

A. MENSURATION PROCEDURES AND DATA INTERPRETATION

The study of mensuration procedures would include as many applications of microdensitometers as possible. Some applications, such as photographic photometry or sensitometry, are reasonably well understood. For these cases, the study effort would consist of optimizing the procedures and clarifying descriptions of consideration such as aperture and optics selection. In other cases, such as the analysis of system performance, procedures for data collection and analysis are not as well understood. Therefore, these procedures have to be developed and it is recommended that experiments be performed to test data reduction techniques as they are developed and to establish limits of error.

As an example, consider the problem of determining the amount of uncompensated image motion in an aerial image. This can be accomplished if the camera static performance is known (say as a transfer function) and if the transfer function of the aerial image can be measured. Procedures developed on Project Q-CAR* indicate that scanning several edges which occur at various orientations in the scene can provide the required information. However, practical questions such as smoothing the scan data to remove noise must be answered. Present smoothing routines create appreciable error in certain cases. The best check of all procedures involved is a series of controlled experiments.

As data analyses such as the above are applied to higher resolution input photographs, the effect of the resolution of the microdensitometer elements becomes significant. The first element to require corrections to

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STATINTL * Contract No. [redacted]

the data is the aperture. Correction for this effect is well known and can be handled in terms of transfer functions, assuming incoherent illumination. As smaller apertures and higher magnifications are used, both the resolution of the analytical optics and the numerical aperture of the illumination system become important. Since this analysis requires solution of equations for partially coherent light and extended objects, the procedures are more complex and in fact solutions are not always available. Ranges over which various approaches are valid would be identified and where general solutions are not available, approximate or "rule of thumb" solutions would be sought.

Research is being conducted by a number of workers on the problems of grain scattering functions and their effect on specular and diffuse density readings. The results of previous investigations would be collated and the correction factors for density readings made with various optics and magnifications would be computed as well as the state of the art permits. These results would be useful in connection with all density measurements.

B. EQUIPMENT CAPABILITY

To determine the merits of existing microdensitometers, the manufacturers would be contacted and detailed information pertaining to available apertures, magnifications and optical limitations, focus tolerances, scan speeds, modes and precision, maximum scan travel, readout media, detector response, electronic circuitry, and light source characteristics would be obtained from system and component manufacturers' specifications.

One item to be considered here will be the development of a standard set of tests which can be used to determine various performance characteristics of microdensitometers. A series of tests lasting about one day per instrument would be conducted using instruments at the manufacturers when available.

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A definition of various instrument classifications (Class 1, 2, etc.) would be determined by considering the performance requirements necessary for utilizing the instrument in various applications. The performance characteristics of existing microdensitometers, including instrument sensitivity determined from noise sources and response times, would be reviewed and correlated to arrive at a classification of each of the instruments.

C. FEASIBILITY STUDIES

Several concepts would be considered which might improve current microdensitometer designs.

The inclusion of a visual display capability to enable the operator to locate more easily the image to be scanned and a microphotographic recording system to provide a permanent record of the scanned image will be considered. While ordinary beam splitting techniques might provide simultaneous image scanning, viewing, and recording capability, they compromise instrument sensitivity by removing a portion of the signal which would ordinarily reach the detector. Techniques such as isolating the scanned area and projecting it onto the detector while projecting the remaining image area onto a high resolution screen, would be studied. Visual display and recording techniques of this type would be studied experimentally with the use of a microscope camera and a micro-image scanner.

The advantages of the use of a continuous-wave laser as a light source in microdensitometers will be considered. Laser intensities can provide a means of measuring densities over a wider range than is currently possible for small apertures and the scattering properties of emulsion grains may be obtained more readily with a monochromatic light source. The use of laser sources introduce several problems, namely, stability, coherence, and life time. Since the stability problem is not unique to laser sources, consideration is deferred until later in the technical section. The use of a source with different coherence characteristics

than ordinary sources will cause measurement effects which require study beyond that proposed under the study of resolution. Since the output power of a laser can be changed by altering the cavity length, which also changes the laser action, laser intensities and coherence in various operating modes will be investigated to determine their limitations as light sources.

With the use of a laser source, aperture shaping could possibly be accomplished by controlling phase aberrations of condensing optics, thus focussing the laser beam into the desired scanning aperture configuration, and eliminating the need for field stop apertures. This possibility will be investigated.

The maintainability, life time, and auxiliary equipment requirements of CW lasers would be considered in this study to determine the practicality of their use with respect to their advantages.

The feasibility of producing a standard density wedge would be studied by determining the calibration requirements of microdensitometers and by surveying the manufacturers of available density standards. Where manufacturers' specifications are not available, tests of various media for possible use as stable, accurate density wedge standards would be conducted.

An additional task to be considered would be the design and testing of a color microdensitometer which would extend the usefulness of the art into the field of spectral photographic photometry. Most existing microdensitometers are "zeroed" by adjusting the light source voltage which also changes the color temperature of the source and hence the spectral response of the instrument. Means such as adjusting light source intensity by using a neutral density continuous wedge would be studied. The use of narrow band interference filters would be considered including the problem of supplying sufficient light intensity to provide adequate response throughout a wide spectrum of wavelengths from the ultraviolet through the infrared.

Light source stability is important in microdensitometry and means of compensating for relative instability of high intensity narrow band light sources have been investigated to some extent. One light source instability

compensation technique considered feasible for use in a microdensitometer consists of coupling the output of two identical detectors. One of these detectors measures the light intensity transmitted through the film while the other measures the light source intensity directly. This coupling technique offers both compensation for light source intensity fluctuations and an alternate "zeroing" scheme.

D. DOCUMENTATION

Monthly progress reports will be prepared as requested, and it is suggested that the results of the proposed study program be documented in separate reports.

The first report would be presented as a handbook on microdensitometry including mensuration procedures and data interpretation schemes as developed in Task I of the proposed program. The theoretical concepts involved in the data interpretation procedures would form an addendum to this report which would be prepared concurrently with the performance of the remaining tasks of the program.

The second report would present the results of the second and third tasks of the program. Included in this document would be a listing of the existing microdensitometers and their specifications and classification. The results of the various feasibility studies will be presented and recommendations for instrument improvement made where possible.

Although it is suggested that the reports be published separately to provide the sponsor with data as quickly as possible, they would be prepared in a form which would allow the incorporation into one document at the end of the effort.

IV. PERSONNEL EXPERIENCE

Assignment of individuals to the program in advance is difficult because of uncertainties as to awards of contracts. Biographies of personnel presently planned for assignment to the program follow. In the event certain individuals are unable to participate, the Laboratory would substitute equally qualified personnel.

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V. RELATED PROJECTS

Brief descriptions of projects follow in which microdensitometry, microimaging, and image quality analyses were performed.

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Photographic Reconnaissance from Space Vehicles (PHOTOREK I) (Completed) [redacted]

This program was a one-year scientific investigation designed to:

1. Analyze the technical requirements for photographic reconnaissance from space vehicles versus available state of knowledge.

2. Derive new techniques and methods to provide the required capability.

3. Determine the extent to which scientific investigations will depend on data collected by research vehicles probing the upper atmosphere and/or the use of facilities to simulate upper atmosphere conditions.

A thorough analysis of the photographic parameters important to high altitude aerial photography provided the basis for performance extrapolation to satellite altitudes. Essential to this analysis was the determination of the physical limitations imposed by atmospheric scattering and turbulence, camera aperture diffraction, photographic emulsion granularity, spatial response, visual detection and resolution thresholds.

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A Program to Develop Instrumentation and Obtain Information Pertinent to Space Photographic Reconnaissance (PHOTOREK II) (Completed) [redacted]

The specific goals of this program were to:

1. Develop and fabricate ground photographic targets and instrumentation to monitor and record appropriate photometric data.

2. Design an airborne recording spectrophotometer.

3. Supply a special image scanning instrument.

4. Analyze pertinent photographic negatives.

Targets and instrumentation were developed to provide a controlled measurement of contrast reduction as a function of altitude for several camera-film-filter combinations. The state-of-the-art of image scanning instruments was investigated and an [redacted] Model 4 STATINTL microdensitometer was specially modified for use in the analysis of the experimental data. A preliminary analysis of the limited amount of data gathered under the contract yielded a relationship between atmospheric transmission and absolute humidity.

A Program to Develop Instrumentation and Obtain Information Pertinent to Space Photographic Reconnaissance (PHOTOREK III) (Current) STATINTL [redacted]

The goals of this phase of the PHOTOREK program are to:

1. Analyze by microdensitometry, pertinent photographic negatives and correlate with auxiliary data from a series of RB 57D-0 flights.

2. Analyze pertinent photographic negatives from high altitude flights by microdensitometry.

3. Develop and fabricate ground instrumentation for use with one portion of the high altitude program.

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Quality Categorization of Aerial Reconnaissance (Q-CAR) (Current) [redacted]

This study is directed toward the derivation and validation of a "summary measure" of image quality. This "summary measure" is intended to provide a useful rating scale by which photographs of high quality ratings would be given priority over those of lower quality. In the study, test photographs were obtained by laboratory modification of originals and resulting parameter values determined by microdensitometry.

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Graphic Format Data Handling Study (GRAFORM) (Current) [redacted]

The object of this study is the selection of the optimum format for storage and retrieval of graphic information, such as reconnaissance, cartographic photography, and charts. Storage techniques and media have been investigated and the most promising have been chosen for more complete analysis by interpretation tests. For the interpretation tests, a microscope camera system was used as a means for simulating photography which would be obtained with advanced systems.

VI. FACILITIES AND EQUIPMENT

Facilities and equipment relevant to the proposed program are described below.

The Environmentally Controlled Optical and Photographic Laboratory

In addition to the Laboratory's standard optical and photographic facilities, a special laboratory with a controlled environment has been established. The clean area of this Laboratory contains over 1000 square feet of floor space and is supplied with air filtered to remove 99.97% of the particles in excess of three-tenths of one micron diameter. The air conditioning also controls temperature and humidity. The air in the room is changed completely every two minutes. A slight excess pressure is maintained to prevent air or dust leakage into the room.

A precisely controlled photographic laboratory has been installed in the clean area to develop photographic films used in recording optical outputs. This capability allows for both cut and roll film processing (black and white, and color) using both mechanical and nitrogen agitation techniques. For control and quantitative analyses, the following equipments are available: a [redacted] Model 1531-C sensitometer, an [redacted] Model 4 microdensitometer with analog-to-digital converter, a microscope with various eyepieces and objectives, a [redacted] QuantaLog Model OP10 densitometer, and an enlarger-reducer. A wide variety of optical components is available including a spectrometer, optical flats, lenses and light sources. Several optical benches, precision clamps and calibrated holders are also available.

Microdensitometer - [redacted] Model 4

The Laboratory-owned standard [redacted] Model 4 microdensitometer features a precision scanning system, high quality illumination and viewing optics, and a high sensitivity photomultiplier detector. It permits image scanning with linear dimensions down to 1 micron, and area dimensions

of 20 square microns, with an output linear to density over a range of o to 4.0. Objects can be positioned with micrometer controls in the horizontal and vertical directions to an accuracy of 2 microns, and also rotated for initial alignment of the image. The short term and long term stability is 0.005 density units, with reproducibility of 0.02 density units. Scanning speeds of 75 microns/minute, 1.2 millimeters/ minute and 20 millimeters/minute are available. The recorder is a Brown paper chart recorder having 1/4 second response, with chart speeds of 2", 4" and 8"/minute. The full scale deflection of 0 to 4.0 density units can also be expanded to provide a full scale range of 0 - 2.0 units. Hence, analysis of photographic imagery with resolutions up to 1000 lines/mm and with wide density ranges can be adequately handled with this instrument. The use of interference and absorption filters permits film analysis in the near ultraviolet.

An analog-to-digital converter processes the output data of the microdensitometer to permit it to be fed into the Laboratory IBM 704 computer. The converter is a punched paper tape system which can be set to sample at any rate up to 10 samples per second.

Enlarger-Reducer

For enlargement and reduction work of higher acuity than that of the Saltzman available in the optical laboratory, an enlarger-reducer employing microscope optics has been fabricated. The high contrast limit of this system is in excess of 1000 lines/mm.

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Micro-Image Scanner

The Laboratory is in the process of purchasing an [redacted] Model 4A microimage scanner. The scanner is an automatic, free-mounted travelling microscopic system. It is equipped with a photomultiplier readout feeding a densitometer circuit with output recorder, and measures the log intensity of an image in the focal plane of the microscope objective.

APPENDIX A

OBJECTIVES FOR A MICRODENSITOMETER CAPABILITY AND INTERPRETATION STUDY

1. Introduction

It is required that an intensive study be made with a class one microdensitometer which will enable the operator to accurately interpret data from this instrument and also to facilitate use of the instrument to its maximum capability. Results of this study will be published in an instruction manual consisting of (a) readout data and its interpretation and (b) the theoretical concepts as a backup to readout data obtained. Information collected from this study will be used for indoctrination of individuals into the art of microdensitometry and should be stated as clearly and precisely as possible. Theoretical concepts will be included as an addendum to the manual. The purpose of the manual would be to realize an instruction capability which is current and reflects the most recent developments in microdensitometry.

2. Subject Requirements

(a) Effect of lens resolution on the reliability of density readings.

(b) Micron and submicron scanning capabilities in respect to grain size, grain clumping.

(c) Relative sensitivity of microdensitometer considering scan aperture size, emulsion or film types, film travel and related readout media.

(d) Relationship of specular and diffuse density readings with respect to scanning aperture, emulsion depth, film types, light sources, processing levels and film densities.

(e) Possible mensuration capabilities determined as a result of the preceding items of study.

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(f) Since a definition of class one, class two, etc. instruments remains unresolved, specific information should be given to define each.

(g) Correlation of systems should be made for existing class one instruments to present data incorporation of all the latest capabilities.

(h) The effectiveness of including a visual scan on a cathode ray oscilloscope and portrayal of scanned area on a high resolution screen.

(i) The feasibility of incorporating a photo micrograph to record any image being scanned.

(j) Research into the possibility of using a laser unit as a light source, including such factors as decay rate, life of unit, auxiliary equipment needed and feasibility study.

(k) Production of a standard density wedge for testing the read-out accuracy of the microdensitometer. Consideration of such media as glass, gelatin or other suitable material should be discussed.

3. Miscellaneous Requirements

(a) Progress reports should be submitted on a monthly basis. Included in this report should be the status of the study/ expenditure to date on an overall percentage comparison and proposed study phases.

(b) The completed manual will be in the following form:

1. Index
2. Introduction
3. Approach
4. Main body of report including photographs, graphs and tables

5. Technical portion serving as backup to main body information

6. Summary

7. Bibliography of reference material

8. Glossary of terms. The definitions of words used must present the exact meaning as used within this study. If more than one interpretation is presented in the study, each shall be defined in the glossary with reference numbers for clarification.

9. Appendix

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TECHNICAL BACKGROUND PROCUREMENT INFORMATION STATINTL

I. Contractor

A. Name and address: [redacted] Contract Officer (cleared for Secret)

B. Evaluation of previous performance: No previous contracts with NPIC. Rated 'Excellent' by ONR, [redacted]

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II. Brief description of this procurement: Detailed procedures and theoretical concepts for microdensitometer operation and data interpretation STATINTL

Estimated total amt. $ [redacted]

A. Deliverable items: Progress reports will be received on a monthly basis giving status of study/expenditure. Handbook of microdensitometry received after completion of 'TaskI' (approximately $6\frac{1}{2}$ months afterward). Results of Task II and Task III (Equipment Capability Study and Feasibility Studies) will be received at the end of the tenth month period.

B. Is this procurement for other than a standard, "off the shelf" or slightly modified commercial item? yes If "yes", is it anticipated that any more of this unit will be procured? No If so, a complete set of directly reproducible manufacturing drawings and specifications would normally be included in this procurement. Comments:

C. Will contract cover a period of more than 90 days? Yes If "yes", are progress reports desired? Yes If so, indicate frequency, content and number of copies desired: Progress reports will be received on a monthly basis in triplicate.

D. Is any Government-owned property to be provided to the contractor? No If so, list and indicate its availability (where, when, etc.)

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E. Is any special tooling involved? No

F. Security:
1. Association with the Sponsor is Classified

2. The specifications and/or drawings are Not classified

3. The item is Not classified

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4. Contractor personnel known to be aware of this proposed procurement:

[redacted]

5. Other security information

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III. Reasons for selection of this source. If other sources were considered, indicate results. If no other sources were considered, list the reasons why this firm is considered to be uniquely qualified to perform this work.

[redacted] was chosen because of their extensive background in microdensitometry, the amount and quality of support instrumentation such as lazers, spertrometers and microdensitometers. In addition it was felt that this company could approach the subject in a more objective manner than a manufacturer of microdensitometers. Cost of this program is [redacted] and extends over a 10 month period.

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Other proposals were received and were considered of no interest from

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A) [redacted] 12 months - program similar to [redacted] but rejected because of cost. Can be considered as alternate to [redacted] proposal.

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B) [redacted] approx.; 6 months-thoroughness and objectiveness questioned.

C) National Bureau of Standards - [redacted] 12 months-covered only calibration and evaluation of microdensitometers.

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IV. Technical contact [redacted] 2610
Name Telephone

In the event additional space is required, use the reverse side(s) of this form, with a reference to the item number to which the comment applies.

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